CMHC SCHL

Helping to house Canadians

Canada

Life Cycle Cost Study Comparing Domestic Hot Water Hot Water Tanks and Boilers as a Space Heating Appliance

Canada Mortgage and Housing Corporation
December, 1990

92-01860/

LIFE CYCLE COST STUDY COMPARING DOMESTIC HOT WATER TANKS AND BOILERS AS SPACE HEATING APPLIANCES

Final Report

Prepared by:

Rick Thrall
and
William J. Mayhew, P.Eng.

HOWELL MAYHEW ENGINEERING, INC.
15006 - 103 Avenue
Edmonton, Alberta
T5P 0N8

July 1990

Canada Mortgage and Housing Corporation, the Federal Government's housing agency is responsible for administering the National Housing Act

This legislation is designed to aid in the improvement of housing and living in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part IX of this act, the Government of Canada provides funds to CMHC to conduct research into social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has the statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

This publication is one of many items of information published by CMHC with the assistance of federal funds.

DISCLAIMER

This document was developed by Howell-Mayhew Engineering, Inc for Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the corporation that assisted in the study and its publication.

CMHC does not assume liability for the damage, injury or expense incurred as a result of the use of this publication.

TABLE OF CONTENTS

	Page
Executive Summary	ii
1.0 Introduction	1
1.1 Background and Issues	1
1.2 Project Objectives	3
1.3 Scope of Work	3
2.0 Life Cycle Costing	4
2.1 Background	4
2.2 Cost Information	4
2.2.1 Initial Capital Cost	5
2.2.2 Annual Operating Cost	6
2.2.3 Annual Maintenance Costs	9
2.2.4 Other Costs	10
2.2.5 Economic Factors	11
2.3 Simple Payback Analysis	12
2.5 Life Cycle Cost Analysis	13
2.5.1 Analysis Criteria	13
2.5.2 Methodolgy	14
3.0 Alternate Scenarios	16
4.0 Existing Heating Systems	17
4.1 Research	17
4.2 Domestic Hot Water Tanks	17
4.3 Boiler Operation	19
5.0 Alternative Heating Systems	20
6.0 Codes and Standards	20
7.0 Conclusions and Recommendations	21
7.1 Cost Effectiveness	21
7.2 Alternate Equipment	21
7.3 Recommendations	22

APPENDIXES

Reported Installation Costs	Appendix "A"
Fuel Calculations	Appendix "B"
HOT-2000 Heat loss Simulation P/O	Appendix "C"
NWTHC Maintenance Costs	Appendix "D"
Example Calculations	Appendix "E"
Recommended Literature	Appendix "F"
Heat Transfer	Appendix "G"

EXECUTIVE SUMMARY

Introduction

The trend towards energy efficient housing has resulted in significant reductions in the space heating load. As a result, the size and output required for heating appliances has also decreased, and the domestic hot water load has replaced space heating as the dominant heating load. The economics of various heating systems is an ongoing question with project managers and building owners. The Northwest Territories Housing Corporation (NWTHC) presently utilizes oil-fired boilers and furnaces to heat their stock of housing units. An alternative heating system which uses a domestic hot water tank for both space heating and hot water heating has been installed in several housing units on a pilot basis. The Corporation wanted to evaluate the cost effectiveness of a domestic hot water system compared to other existing equipment. A Life Cycle Cost study comparing the boiler and the domestic hot water tank system was considered the most effective method of determining equipment cost effectiveness.

Project Objectives

The project objectives were:

1. to establish and compare the life cycle costs of both a domestic hot water tank space heating system and a boiler space heating system;
2. to determine if there are higher efficiency domestic hot water tanks on the market and what can be done to improve existing efficiency rates; and
3. to research other space heating alternatives and determine their cost effectiveness.

Investigation Method

Actual costs for equipment installation and maintenance were compiled from the records of the NWTHC and from a Yellowknife mechanical contractor who originally installed the systems. Fuel consumption was established by developing a model of a standard house using a computer-based heat loss simulation program. The heating loads for cold climate houses located in both an urban area and a remote area were established using this model. Fuel efficiencies for the boiler and domestic hot water (DHW) equipment being used by the NWTHC were used to determine the fuel costs for an average year in both locations. These capital and operating costs were then used to carry out the analysis.

Telephone interviews with government agencies, research groups, utilities and manufacturers were used to determine trends in home heating, equipment availability and alternative heating systems compatible with the needs of the NWTHC.

Conclusions and Recommendations

The Life Cycle Cost analysis, utilizing the economic factors and costs determined for this project, indicated that the DHW tank space heating system is a viable investment.

Fuel costs have a significant impact on the economics of choosing a lower efficiency appliance as a space heater. If energy prices or fuel consumption increases, the domestic hot water system becomes less economical than the higher efficiency boiler. An increase in the inflation rate has the effect of making the DHW system more economical than the boiler system.

The NWTHC should upgrade the type of domestic hot water space heaters they purchase and install in homes. The GSW John Wood 307 which is presently being used can be readily upgraded or a high efficiency domestic hot water tank can be purchased from several other manufacturers.

Advances in heating equipment technology should be continually reviewed by NWTHC staff and improved equipment designs considered for use in northern housing applications.

1.0 INTRODUCTION

1.1 Background And Issues

In the Northwest Territories (NWT), a conventional hydronic boiler system is the predominant space heating appliance in public housing. Domestic hot water is provided by a companion water tank which is heated by a coil from the boiler (Figure 1).

In recent years, however, the Northwest Territories Housing Corporation (NWTHC) has been upgrading the insulation levels in their homes to the point where the reduced heating load allows for the use of smaller heating appliances to provide the necessary space heating requirements. In response to this change, the NWTHC received temporary code exemption that allowed them to use hot water tanks to provide both domestic hot water (DHW) and space heating requirements. The DHW tank heats the water which is circulated through a radiant baseboard loop throughout the house and returned to the cold side of the tank (Figure 2).

This method of heating is being considered as a replacement for the conventional boiler system. An initial CMHC study, the *Field Investigation of Domestic Hot Water Tanks as Space Heating Appliances,* showed that a DHW tank used in this manner does not deteriorate more quickly than a tank in normal service and suggested that it may be more economically feasible.

The NWTHC found from their initial calculations that the use of a DHW system would be the most effective utilization of resources. Their research showed that the tanks were less expensive to purchase, install and maintain than a conventional boiler. Their concern was that the lower efficiency of the DHW system compared to a boiler would erode the capital cost savings over the life of the system.

It was known that the capital cost of purchasing a DHW system is less than that of the boiler. However, in order to determine if it is feasible to install and operate these innovative systems, a more complete analysis had to be carried out. It is important for the consumer of the technology to appreciate the ongoing costs of operating the appliance and not simply have the builder install the system which is most economic for his interests. In order to fully document the costs associated with a DHW tank space heating system, a Life Cycle Cost study was required.

The regulatory difference between a domestic hot water tank and a boiler is that the latter is designed and approved specifically for use as a space heater while the former is not. New and innovative equipment can undergo the necessary testing to gain approval for use as a space heater but all heating appliances must receive this approval by the governing body prior to installation in a specific application. Until a DHW tank is

formally approved for use as a space heating appliance it can only be installed as a potable water heater, unless special exemption is provided.

The United States recently granted approval, in all states, for the installation and use of DHW and integrated space heating systems in residential housing. In the future, it is possible that Canadian authorities will follow the American lead and also grant approval for domestic hot water tanks to be used as space heating appliances.

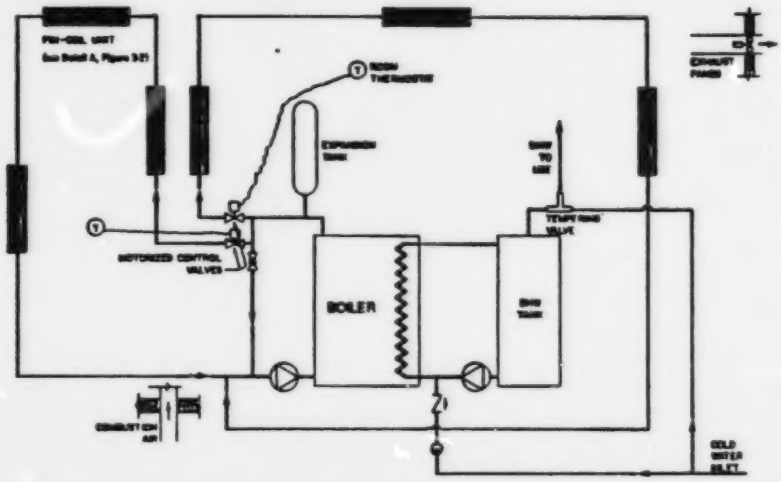

Figure 1. Conventional Boiler Heating System

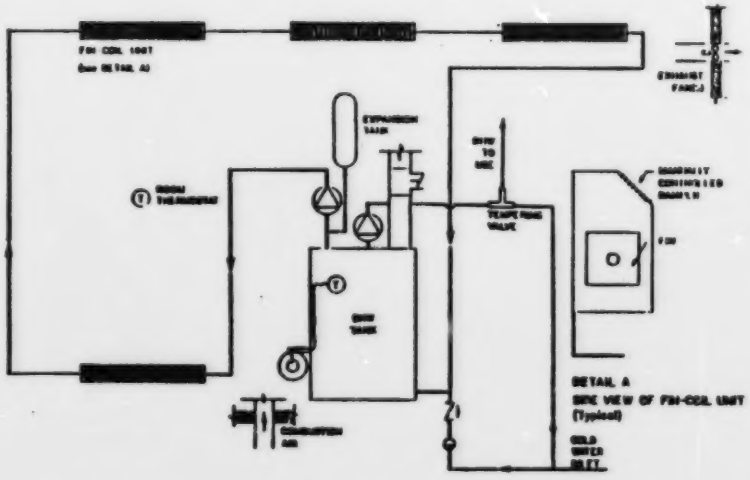

Figure 2. Hot Water Tank Heating System

1.2 Project Objectives

The project objectives were as follows:

1. to establish and compare the life cycle costs of both a domestic hot water tank space heating system and a conventional hydronic boiler space heating system;

2. to determine if there are higher efficiency domestic hot water tanks on the market and what can be done to improve existing efficiency rates; and

3. to research other space heating alternatives and determine their cost effectiveness.

1.3 Scope Of Work

The scope of work carried out to meet the project objectives was limited to the following set of conditions:

1. The Life Cycle Cost (LCC) analysis was limited to systems in two regions in the NWT which individually represent an urban environment and a remote environment.

2. Methods to improve existing efficiency rates was limited to equipment available on the market.

3. The cost effectiveness of space heating alternatives was determined only if they appeared to be economically feasible.

2.0 LIFE CYCLE COSTING

2.1 Background

When decisions about design alternates at different capital costs are to be made, the future benefits from the higher cost alternates must be established and evaluated to justify the expense. Life cycle costing integrates all of these aspects in a framework based on the value of money over time. LCC is a method of calculating the total cost of ownership over the life span of the asset. Initial costs and all subsequent significant costs are included in the calculations as well as salvage value and any other quantifiable benefits.

The objectives of using the Life Cycle Cost (LCC) approach to analysing an item's viability are:

1. to develop a well-defined model from which various alternatives can be appraised in a fair and logical manner;

2. to derive the preferred economic solution to equipment selection problems from all available alternatives; and

3. to provide an analytical tool that can establish the interaction between planning and selection decisions and long term costs.

This study evaluates the life cycle costs of a conventional hydronic boiler and a domestic hot water tank used as space heating appliances in the Yellowknife area and the Eastern Arctic. The Yellowknife area installations were located in the communities of Dettah, Latham and Hay River and are representative of an urban environment where materials and skilled trades are readily available. The Eastern Arctic communities investigated were the remote towns of Repulse Bay and Hall Beach, where a limited supply of materials and a lack of available skilled labour are typical. The cost analysis of these two uniquely different regions provided an evaluation of the possible extremes for the installation of heating equipment.

2.2 Cost Information

This LCC study treats design decisions as investments in equipment. An equipment investment is not limited to the initial purchase price of the product but must also consider the ownership costs over the life of the investment.

For the analysis of the different heating systems, the following costs and economic factors were required:

1. Initial Capital Costs
   - o Equipment costs
   - o Shipping costs
   - o Installation costs

2. Annual Operating Costs
   - o Fuel costs
   - o Fuel consumption
   - o Equipment efficiencies
   - o Electrical costs

3. Annual Maintenance Costs
   - o Repair costs
   - o Equipment life span

4. Other Costs
   - o Equipment replacement costs
   - o Salvage value of used equipment

5. Economic Factors
   - o Discount rate
   - o Inflation rates
   - o Fuel escalation rates

2.2.1 Initial Capital Cost

The NWTHC typically installs boiler systems in their units. However, as a pilot project, they have installed a limited number of DHW heating systems in their public housing. Many of these systems were installed by J & R Mechanical, a firm located in Yellowknife. Information supplied by J & R Mechanical and the NWTHC were used to determine the actual cost of both boiler and DHW systems when they were installed in similar dwelling units in the Yellowknife area and in the Eastern Arctic. These capital costs include the expenses for the equipment purchased, the installation of the systems and the shipping costs.

The Yellowknife costs, provided by J & R Mechanical, were specifically for the heating system whereas the Eastern Arctic costs included all of the plumbing and heating equipment associated with the construction of the house. The Eastern Arctic capital costs were prorated on a percentage basis to eliminate the extraneous costs and focus on the heating system. Equipment purchase costs for the systems included all the materials related to the heating system. In addition to the primary heating system, this materials list included pumps, zone valves, finned radiators, chimneys and all other heating system components. Letters stating the installed costs and the billing breakdown are attached as Appendix "A". Note that airfare was

not included in the installation costs since it would be the same cost whether the contractor was going to install a DHW or a boiler system.

The initial capital costs were as follows:

	YELLOWKNIFE		EASTERN ARCTIC	
	a) Boiler	b) DHW	a) Boiler	b) DHW
Equipment Cost	$4,334	$2,324	$5,715	$4,120
Installation Cost	$300	$160	$2,146	$1,134
Shipping Cost	$120	$45	$1,807	$1,200
Initial Capital Cost	$4,754	$2,529	$9,668	$6,454
Additional Cost (a-b)	*$2225*		*$3214*	

The cost breakdown showed that the initial capital cost of a DHW system was $2225 less expensive in the Yellowknife area and $3,214 less expensive in the Eastern Arctic than a boiler system. (Each system provides both potable hot water and space heating.)

NOTE: Although the *Initial Capital Cost* is accurate for each region, the costs for equipment, installation and shipping were not accurately segregated. Costs of the initial equipment purchase includes some of the installation costs in both regions. Since costs and accounting methods in the two regions may vary significantly, it is essential not to compare the *Equipment Cost* in each region.

2.2.2 Annual Operating Cost

The annual operating costs were determined using fuel costs, fuel consumption and equipment efficiencies. Based on the detailed information of these parameters given below, the annual operating cost to provide both space and domestic hot water heating in the two communities were as follows:

	YELLOWKNIFE		EASTERN ARCTIC	
	Boiler	DHW	Boiler	DHW
Annual Operating Cost	$432	$616	$1112	$1584

These costs show that the annual cost of operating the DHW system is greater in both regions - $184/year more expensive in the Yellowknife area and $472/year more expensive in the Eastern Arctic.

a) Fuel Costs

The primary space heating fuels used by the housing stock in the north are oil, propane, natural gas, electricity and wood. The NWTHC uses #2 grade home heating oil for heating in 95% of their housing units.

The cost for #2 heating oil throughout the Territories appears to vary widely. In the Yellowknife area, Housing Corporation management quoted prices ranging from $0.2643/L to $0.335/L. In remote areas, such as Hall Beach and Repulse Bay, in the Eastern Arctic, the prices were quoted between $0.389/L and $0.54/L . Due to the inconsistency of fuel price records, the analysis was carried out using average values. The energy costs used in this analysis were $0.27/L for Yellowknife and $0.45/L the Eastern Arctic. Support calculations for fuel consumption are listed in Appendix "B".

b) Fuel Consumption

The NWTHC provided the construction specifications for a typical public housing unit - a two story unit with a 100 square meter floor plan. The HOT-2000 computer-based heat loss simulation program, developed by Energy, Mines and Resources, Canada, was used to model identical homes in Yellowknife and Repulse Bay and determine the fuel consumption in each of these locations (Appendix C).

The HOT-2000 analysis was carried out assuming a fairly tight house having 0.3 air changes seasonal natural infiltration. No mechanical ventilation was used. This figure is based on information from NWTHC and seems reasonable considering:

- o there is no basement;
- o the walls are prefabricated stress panels;
- o the units are small and of two-storey construction;
- o there are only 3 or 4 windows and 1 door; and
- o the mechanical room is separated from the house.

The HOT-2000 annual oil consumption predictions for the combined space heating and domestic hot water heating for both systems in both locations were as follows:

	YELLOWKNIFE		REPULSE BAY	
	Boiler	DHW	Boiler	DHW
Fuel Consumption (L)	1600	2280	2470	3520

c) Boiler Efficiency

Boilers and furnaces are rated by AGAMA with efficiencies calculated as an *annual fuel utilization efficiency* (AFUE). The AFUE, which includes on/off cycling, is defined as an appliance's operating efficiency during the heating season. According to AGAMA, the AFUEs of oil-fired boilers range between 74.5% and 88.7% depending upon the design and output rating of the unit. The two models used by the NWTHC are rated at 84.1% and 86.1%. which are higher than most similarly sized alternate boilers.

Little research has been conducted on the efficiency of combination boiler which includes a storage tank. Boiler efficiency is reduced because of standby losses from the storage tank and short cycling for domestic hot water in the summer. Recent research by Brookhaven Laboratories suggests that the efficiency of the combination boiler is approximately 77%. This figure was used in this investigation.

d) Domestic Hot Water Tank Efficiency

Domestic hot water tanks are rated by AGAMA using an efficiency calculated as an *energy factor* (EF). The EF is defined as a measure of the overall efficiency of a water heater based on the model's recovery efficiency, stand-by loss and energy input.

According to AGAMA, the EF of oil-fired DHW tanks range between 50% and 63%. In order to gauge the ability of a tank to provide hot water, a "first hour rating system" has been established and is defined as the amount of water which can be supplied by the system at the set temperature over the first hour of operation. It is a combination of the amount of water stored in the water heater and the time required to heat cold water to the desired temperature. Units with higher first hour ratings will be more capable of meeting the heating requirements of cold climate housing. The range of first hour ratings is between 350 litres (92 US gallons) and 500 litres (130 US gallons).

The DHW tanks used by the NWTHC are rated at an EF of 54% and are notably one of the lowest efficiency units available. The first hour rating of these units is 430 liters (113 US gallons).

e) Electrical Costs

Electrical consumption data for the heating systems was not available. Based on consumption figures for these two types of systems published in the CMHC report *Alternate Heating Strategies, May 1988,* the annual electrical consumption of the DHW system is approximately 150 kWh more than the boiler system. This is due to the fact that the DHW system operates for longer periods of time.

Using average electrical rates for each area, the increased electrical cost of operating the DHW system would be approximately $10 in the Yellowknife area and $50 in the Eastern Arctic. For the purpose of this analysis, the increased electrical costs were included with the fuel costs.

2.2.3 Annual Maintenance Costs

One of the problems that NWTHC faces is the maintenance of housing units built in remote areas. These units are rented through a local housing authority which has the responsibility of maintaining them with a staff often unqualified to handle complex heating systems. Problems with simpler heating systems are easier to troubleshoot and correct. If a tradesman from Yellowknife has to be flown into the remote location to fix a complicated boiler, the cost of the repair increases.

The availability of parts is essential when dealing with extremes in climate and the vast area of the NWT. It was found that the parts for a conventional domestic hot water tank were readily available and could easily be shipped and installed, whereas the parts for a boiler were not always available and were often much more difficult to install.

Actual costs for equipment maintenance and fuel were compiled from the records of the NWTHC for the Hay River District and the Dettah/Latham communities. Since neither of these communities are considered remote, maintenance costs for the Eastern Arctic were estimated.

NWTHC collected cost comparison data on 410 housing units in the Hay River District. The average maintenance cost over a 10 month period was $280/unit. The heating system breakdown for this same period showed that boilers averaged $242/unit (furnaces averaged $298/unit). The NWTHC has not tracked the maintenance costs of DHW tanks as space heating systems. The maintenance records they provided combine maintenance costs of a conventional DHW tank with other large household appliances. It has been estimated that the maintenance cost for DHW tanks as space heating appliances is about $90/unit. The average annual maintenance costs for the boiler and DHW tank were $290 and $54 respectively when extrapolated over a full year and other household appliance costs were deducted from the DHW tank cost.

Since there were no records for the Eastern Arctic, the annual maintenance costs were estimated at twice the costs for the same equipment installed in Yellowknife. Appendix D lists the maintenance costs supplied by the NWTHC. It should be noted that the two heating systems were operated in the space heating mode all year long and no adjustment for the summer months was made by the homeowners or NWTHC.

The annual maintenance costs are as follows:

	YELLOWKNIFE		EASTERN ARCTIC	
	Boiler	DHW	Boiler	DHW
Maintenance Costs	$290	$54	$580	$108

These costs show that the annual cost of maintaining the boiler system is greater in both regions - $236/year more expensive in the Yellowknife area and $472/year more expensive in the Eastern Arctic.

2.2.4 Other Costs

a) Equipment Replacement

An additional system maintenance cost used in this study was the cost for the replacement of equipment components. The typical life for a DHW tank is estimated to range between 8 and 12 years and that of a boiler is between 15 and 25 years. Prior to installing the DHW tank heating systems, it was anticipated that the life of the tanks would be reduced to about 5 years. It appeared that it would be a less expensive commitment to purchase and ship a new tank and get the local authority to install it than it would to initially install the longer life boiler system.

A field survey of DHW tanks used as space heaters was carried out by Howell Mayhew Engineering for CMHC in 1989. This survey concluded that the life and maintenance costs of the tanks was not adversely affected by the additional service load.

For this study, the DHW tank was anticipated to operate for 10 years, after which the tank alone had to be replaced. With the average boiler life estimated at 20 years this means that the tanks were replaced once. It was anticipated that the cost of the replacement tank would not change beyond the effects of time on the money over the 20 years. Today, the cost of purchasing a tank alone in Yellowknife is approximately $650, and the cost to install it in the same area is approximately $200. These costs will be affected by inflation. With regular maintenance, the oil burners on both systems will last for the twenty year term.

The replacement costs in remote areas will vary depending on the skills of the Local Housing Authority. If the labour can be provided locally, which is typical, then the costs for installation of equipment will be similar to that of the Yellowknife area. The NWTHC has suggested that the cost for a local individual to install a domestic hot water tank would be approximately $300. In our analysis the replacement price for a tank in the remote north was $975 for the new tank including shipping and $300 for the installation labour.

b) Salvage Value of Equipment

The cost analysis was carried out assuming an equipment lifespan of 20 years. Since, at the end of this length of time, the salvage value of equipment is generally considered to be zero, this was the value used for the cost analysis.

2.2.5 Economic Factors

The effects of time on the value of money must be considered in determining the costs of equipment over a long service life. For this study a discount rate of 7%, an inflation rate of 5% and a fuel escalation rate of 4% were used.

a) Discount Rate

The discount rate is the rate used to relate present and future dollars. When considering expenses and costs over a time period, it is essential that a discount rate be used to reflect the fact that dollars spent or received in the future are worth less than dollars spent or received in the present. The discount rate is typically expressed as a percentage. This rate can be established at various levels but is often set at a lending interest rate or at the desired rate of return. Depending on the source of the funding for the purchase of the heating equipment it may be necessary to use a different factor in calculating the economic equation. For instance, federal government funding will be provided at a different discount rate than funding which is developed through a bank loan. Based on the average savings account investment rate which was expected to be available to Canadians over the next 5 years, the calculations in this project used a discount rate of 7%.

b) Inflation Rate

The inflation rate for various materials and services can vary dramatically over the course of a long term analysis. It is this inflation rate which affects the value of the money in subsequent years of the analysis. Without inflation, the cost of purchasing or maintaining equipment in ten years would be the same as it is today. The Conference Board of Canada suggests that the inflation rate over a twenty year period is difficult to determine. The rate, which is established based on the Consumer Price Index, can vary depending on what commodity or service sector is being analyzed. Based on the estimated average inflation rate for the construction sector of the economy the calculations in this analysis used a rate of annual inflation of 5%.

c) Fuel Escalation Rate

If our heating equipment alternatives operated at the same efficiency, the escalating cost of heating fuel would not be a concern in evaluating the cost effectiveness of the alternatives. However, if equipment is operating at varying efficiencies, as was the case with the heating systems being analyzed, then the margin between one system and another becomes greater over time. It is estimated by the Alberta Energy Resource Conservation Branch that #2 home heating oil will increase in cost by 3.2% on the low and 4.4% on the high side over the next 15 years. For our analysis a 4% fuel escalation factor was used as an average.

2.3 Simple Payback Analysis

A simple payback analysis of additional investment is the most basic calculation to determine the value of an alternative equipment purchase. It is often the first calculation carried out by a purchaser to evaluate the potential return on investment of a product selection. This evaluation compares the additional capital cost to the annual savings of each system. A simple payback analysis does not account for the investment potential of the initial capital cost or other economic factors.

The formula for Simple Payback (SP) is:

$$SP = \frac{\text{Additional Capital Costs (ACC)}}{\text{Annual Savings (AS)}}$$

where:
ACC = Boiler Initial Capital Cost - DHW Initial Capital Cost
AS = Boiler Annual Operating Cost - DHW Annual Operating Cost

The following costs from Section 2.2 were used to determine SP:

	YELLOWKNIFE		EASTERN ARCTIC	
	a) Boiler	b) DHW	a) Boiler	b) DHW
Initial Capital Cost	$4,754	$2,529	$9,668	$6,454
Additional Cost (a-b)	$2225		$3214	
Maintenance Cost	$290	$54	$580	$108
Fuel Cost	$432	$616	$1,112	$1,584
	$722	$670	$1,692	$1,692
Annual Savings (a-b)	$52		$0	

The simple payback calculation indicates that there is no payback on the extra investment for a boiler when it is located in either the Yellowknife area or the Eastern Arctic because a boiler's capital and annual costs are more than, or equal to, a DHW system's costs. The extra capital expense of a boiler system cannot be recovered through operating savings during the life of the equipment in either Yellowknife or the Eastern Arctic. Therefore, according to this calculation, a DHW system is the most economical choice.

2.5 Life Cycle Cost Analysis

A Uniform Annual Cost (UAC) method was used to determine annual life cycle costs over the life of the equipment. This method considers the effects of economic factors and varying equipment lifespans on the value of money over time and reflects the benefits of an investment in terms of today's dollars, or "Present Value" dollars.

In addition to the initial capital, maintenance and fuel plus increased electrical costs (Section 2.2), the equipment replacement and salvage value costs are used to determine the present value costs of the heating equipment (Section 2.2.4). Note, that since the salvage costs are zero, they have not been included in the following calculations.

A summary of the costs used for this analysis are as follows:

	YELLOWKNIFE		EASTERN ARCTIC	
	Boiler	DHW	Boiler	DHW
Initial Capital Cost	$4,754	$2,529	$9,668	$6,454
Maintenance Cost	$290	$54	$580	$108
Fuel/Incre. Elec.Cost	$432	$626	$1,112	$1,134
Annual Replacement Cost		$85		$127

2.5.1 Analysis Criteria

The present value of the initial capital costs for a heating system is affected by economic conditions (Section 2.2.5). The UAC method utilizes economic factors to determine a present value for the money spent on each system. These present value costs can then be used to determine uniform costs on an annual basis. The total lifetime investment is rationalized using a factor called the Uniform Capital Recovery Factor. This factor allows

the costs to illustrate the lifetime investment being paid out in equal annual payments. In this way, it can be established which alternative is the most economical.

The present value of the fuel and maintenance costs, over the period of the analysis, must be calculated to account for investment interest, inflation, and cost escalation over the time period. A fuel escalation factor of 4% and a discount factor of 7% were used in calculating the present value of fuel. The maintenance costs were determined using an inflation factor of 5% and a discount factor of 7%.

The analysis included equipment replacement costs by comparing the cost of the two heating systems over the lifespan of the longer one, and then considering the replacement costs, including labour, for the unit with the shorter lifespan. The boiler had the longest lifespan which, on average, was expected to be 20 years. As a result, a 20 year period was used in this life cycle cost analysis.

2.5.2 Methodology

The formula for Uniform Annual Cost (UAC) is as follows:

UAC = Present Value(PV) X Uniform Capital Recovery(UCR)

where:

$$PV = \text{Today's Annual Cost} \times \frac{(1+e)^1 + (1+e)^2 + \ldots + (1+e)^n}{(1+d)^1 + (1+d)^2 + \ldots + (1+d)^n}$$

$$\text{Uniform Capital Recovery} = \frac{d(1+d)^n}{(1+d)^n - 1}$$

where:

e = Escalation or Inflation Factor
d = Discount Factor
n = Number of Years

The initial capital costs are added to the present value of the annual fuel and maintenance costs for each installation. To these costs, the present value of the replacement equipment required over the analysis period was added. Sample present value calculations are attached as Appendix "E".

	YELLOWKNIFE		EASTERN ARCTIC	
	Boiler	DHW	Boiler	DHW
Initial Capital Cost	$4,754	$2,529	$9,668	$6,454
PV Maintenance Cost	$4,786	$891	$9,572	$1,782
PV Fuel Cost	$6,496	$9,278	$16,715	$24,571
PV Replacement Cost		$1,403		$2,096
PV Cost Per System	$16,036	$14,101	$35,955	$34,903

The present value costs for the systems are converted to uniform annual costs in order to consider the total effects of time on the value of the original investment and operating costs over the life of the investment.

	YELLOWKNIFE		EASTERN ARCTIC	
	Boiler	DHW	Boiler	DHW
PV Cost Per System	$16,036	$14,101	$35,955	$34,903
UCR, 20 years @ 7%	.09439	.09439	.09439	.09439
Uniform Annual Cost	$1,514	$1,331	$3,394	$3,294

Based on the assumptions made for the economic factors, this is the amount of money that would have to be put away each year in order to cover the costs in future years. Therefore, the life cycle cost analysis using the Uniform Annual Cost method indicates that the DHW tank is the more economical alternative in both locations.

3.0 Alternate Scenarios

The following alternate economic scenarios illustrate the effects of variations in the economic factors used in the original analysis (Section 2.5.2).

The variables, indicated using a percentage figure, represent the following economic factors.

%/ % / % = fuel escalation / inflation / discount

VARIABLES	UNIFORM ANNUAL COSTS			
	YELLOWKNIFE		EASTERN ARCTIC	
	Boiler	DHW	Boiler	DHW
4% / 5% / 7%	$1,514	$1,331	$3,394	$3,294

This is the result of the original analysis which indicated a DHW system is the most economical.

4% / 5% / 10%	$1,588	$1,352	$3,529	$3,352

An increase in the discount rate increases the economic attractiveness if the DHW system economically.

4% / 7% / 7%	$1,609	$1,377	$3,586	$3,372

An increase in the inflation rate increases the economic attractiveness if the DHW system economically.

5% / 5% / 7%	$1,573	$1,416	$3,548	$3,520

An increase in the rate of fuel escalation reduces the economic attractiveness of the DHW system.

Double Fuel Used	$2,127	$2,207	$4,973	$5,614

An increase in the consumption of fuel makes the boiler the more economically attractive heating system.

4.0 EXISTING HEATING SYSTEMS

4.1 Research

The American home heating industry has an enormous market and a large variety of manufacturers supplying equipment. The primary energy sources in North America are gas and electricity, therefore, little has been done to specifically advance the state of the oil-fired hot water heater or boiler. The advancements in gas-fired equipment have allowed manufacturers to implement design changes to oil-fired equipment at little additional development cost.

Several concerns were noted from various sources through the course of carrying out research into the use of DHW tanks as space heaters. Although the answers to these questions fall outside of the scope of this project, they should be considered and evaluated prior to a commitment to full implementation of these systems. The questions regarding the use of DHW systems which arose are as follows:

1. If the reservoir water tank runs out of water due to a leak or a late water tanker delivery, is the unit safeguarded against a space heating system failure?

2. Is there a risk of drinking contaminated potable water when the heating lines are opened in the fall after a long dormant period? The heating system plumbing lines will remain closed for several months during the summer and there is concern that bacteria or lead will accumulate in the copper lines.

3. What is the implication of using less efficient combustion equipment to save money when more efficient equipment is readily available? The north is seen as a fragile environment which cannot afford the effects of additional carbon-based fuel combustion and the associated material waste.

It was apparent from interviews with government personnel and industry members that the above questions were of consistent concern to individuals knowledgeable in this area.

A list of recommended reference papers and news articles, supplied in part by Union Gas Limited of Chatham, Ontario, is attached as Appendix "F".

4.2 Domestic Hot Water Tanks

Both a DHW tank and a boiler are capable of providing hot water for use in heating a residential dwelling. However, they provide the required heat in different ways. The domestic hot water tank is essentially a sealed kettle which has a fire under it to heat

the contents. There are sensors which control the firing of the flame and the temperature of the output water, but basically it is a simple kettle. Even when hot water isn't being consumed, the tank must be kept at its operating temperature. This system is only able to provide a continuous supply of hot water approximately equal to its original storage capacity. It cannot heat cold incoming water fast enough to supply an unlimited amount of hot water.

Although hot water tanks were designed in times when natural gas was inexpensive and efficiency was not a strong consideration, the times and the equipment have changed. Modern DHW tanks utilize a variety of design innovations to extract the energy from the heating fuel.

The traditional DHW tank is designed with a firing pot located below a water tank which surrounds a center flue. Higher efficiency DHW tanks have been designed for the natural gas market because this is such a large segment. However, several of the innovations have been included in the construction of the oil-fired heater. Some of the new design features used by oil fired heaters include the following:

Improved Burners - One of the standard improvements is the use of a high efficiency oil burner.

Turbo Baffle - A large single center flue which incorporates a finned baffle aids in heat transfer by increasing heat transfer area and creating turbulence.

Multiple Flues - Three flues are used instead of the conventional one running the height of the tank. This provides for more surface area and, therefore, more heat exchange.

Floating Tank - This is a tank within a tank. The internal tank contains the water while the external tank is essentially a flue which allows the hot combustion flue gasses to surround the entire water tank surface.

The basic criteria in most of these design features is to increase heat exchange surface area and combustion gas turbulence in an effort to enhance heat transfer. High efficiency burners produce more heat energy per unit of fuel than do lower efficiency burners.

4.3 Boiler Operation

A boiler is designed to provide hot water on a continuous basis. It has limited storage capacity, yet is designed to heat cold water quickly to meet the demand. Its ability to heat water continuously is relative to the volume and temperatures of both input and output water.

The following are reasons why boilers are more efficient as space heating appliances:

1. A boiler injects the fuel and air mixture into the combustion chamber in a manner which creates turbulence. It is this turbulence which breaks down the static gas barrier present adjacent to the steel chamber liner. This static gas barrier is an effective insulator and significantly reduces the heat transfer to the steel. Without this barrier the heat energy transfer to the steel jacket and then to the water is much more efficient. This controlled combustion is the primary factor in allowing the unit to extract energy from the input fuel more efficiently. (See Appendix "G" for a heat transfer diagram).

2. A boiler utilizes more surface area for contact between the heat energy source and the water. This allows for greater transfer of heat energy to the water and therefore, less waste of this energy.

3. They have limited stand-by tank losses. A boiler does not have a holding tank which, when not in use, is radiating heat energy to the space. Energy is only added to the system when there is a call for heat from the controller.

5.0 ALTERNATIVE HEATING SYSTEMS

Modern heating systems primarily are either radiant or forced air. Radiant heating takes the form of electrical resistance panels, hot water coils or baseboard heaters. Forced air systems typically consist of either a fossil fuel source or an electric source heating an exchanger past which household air is circulated. Only recently has the combination of increased fuel costs, reduced space heating loads and advanced technology created an incentive to evaluate our household heating requirements. The result is that several high efficiency furnaces, boilers and hot water tanks are now available in the marketplace. The largest area of improvement is in the natural gas equipment sector, as this is the dominant market for manufacturers. However, improvements in gas equipment has influenced the design of other heating equipment. The design changes for DHW tanks are noted in section 4.2.

Although not applicable for use in the remote Arctic communities, a recent and dynamic alternative which has entered the marketplace is the integrated heating system. Integrated systems are typically compact, high efficiency combination potable water and space heating appliances. These systems are designed to have outputs of between 50,000 and 110,000 BTUs, which would allow them to be used in a variety of design applications. At present integrated systems are only available for natural gas and propane fired installations.

From the interviews carried out and the literature review, no effective alternatives beyond the use of improved efficiency DHW tanks were found to be compatible with the requirements of the NWTHC.

6.0 CODES AND STANDARDS

To date, the Canadian National Building Code does not allow for the use of a domestic hot water tank as a space heating appliance. The equipment is not approved for use as a space heater by the Canadian Standards Association or by the Canadian Gas Association. Therefore, it cannot be installed for use in a building unless code exemption is provided.

In the United States, the American National Standards Institute(ANSI) has recently amended the standard which affects the use of DHW heaters, allowing them to be used as space heaters. The U.S. standard for this application is Z21.10.1.

On April 11-13, 1990, the Canadian Gas Association is holding a meeting to discuss codes and standards related to residential domestic hot water heater. These standards have not been formally discussed for about two years and it is at this meeting that the subject of a revision will be tabled.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Cost Effectiveness

The Uniform Annual Cost analysis, utilizing the economic factors and costs available for this project, indicates that the DHW tank heating system is a viable long term investment. Simplified analysis methods did not produce the same conclusions as the detailed analysis. The Annual Expense analysis indicated that although a DHW system is economical in Yellowknife, a boiler should be selected in the Eastern Arctic. The Simple Payback analysis indicated that a DHW system is the most economically feasible choice in either location.

Economic factors which effect the fuel costs have the greatest influence on the results of the Uniform Annual Cost analysis. As the energy cost, the escalation rate, or the fuel consumption increased, the DHW system became less economical. An increase in either the discount or inflation factors had the effect of making the DHW system more economical than the boiler system.

In the event that equipment or installation costs were to increase uniformly for both systems, the DHW system would increase in economical attractiveness over the boiler system.

7.2 Alternate Heating Equipment

At present, the only option which the NWTHC can institute to increase their cost effectiveness is to upgrade the type of domestic hot water heater they purchase. The GSW John Wood 307 which is presently being used can be readily upgraded with an Italian burner made by Reillo. This high efficiency burner would add little to the cost of the system yet would increase system efficiency.

In addition, manufacturers other than GSW can supply higher efficiency tanks than are now being used. These manufacturers are located in the United States but can supply to Canada. The manufacturers include, but are not limited to, Bock Water Heaters, the Carlin Company, Ford Products Corporation and Rheem Manufacturing Company. Each of these systems should be priced and availability of parts and services confirmed. A decision can then be made on which system will meet the needs of the housing corporation.

It is important that the housing corporation remain in contact with improvements in the heating systems industry. There will continue to be advances in integrated heating system technology and eventually an oil-fired system is expected on the market. This type of system may be attractive for use in the north.

7.3 RECOMMENDATIONS

The NWTHC should review the available DHW tanks and select a reliable, high efficiency tank for installation in new houses or as a replacement for existing tanks as required. Future installations and operating costs should be closely tracked so that cost analysis using consistently accurate figures can be undertaken.

As the existing GSW oil burners require replacement, they should be replaced with the high efficiency Reillo burner. This burner is available from the tank manufacturer, GSW Industries.

Advances in heating equipment technology should be reviewed by NWTHC staff and improved equipment considered for use in northern housing applications.

APPENDIX "A"

REPORTED INSTALLATION COSTS

J & R MECHANICAL LTD.

P.O. BOX 1541 - YELLOWKNIFE, N.W.T. X1A 2P2
873-2392 920-2495

January 31, 1990

Howell-Mayhew Engineering, Inc.
15006 - 103 Avenue
Edmonton, Alberta T5P 0N8

Attention: Rick Thrall

Dear Rick:

Re: Heating Comparisons

The units I have compared are 10 units in Hall Beach which used hot water tanks for heating and 5 units in Repulse Bay which used boilers. Freight to each place was shipped out of Montreal port by barge.

	10 UNITS - Hall Beach		5 UNITS - Repulse Bay	
	Total	Per Unit	Total	Per Unit
Wages	$24661.00	$2466.10	$19512.00	$3902.40
Air Travel	20930.00	2093.00	19026.00	3805.20
Material	89501.00	8950.10	51646.00	10392.20
Freight	26031.00	2603.10	16430.00	3286.00

These are the actual costs which occured. The freight rates were the same for Repulse Bay and Hall Beach but the extra costs which occured on the unit basis could be contributed to the boiler, glycol being heavier and would take longer to install. The houses were about the same size but the design of the mechanical was somewhat different.

Hoping this will help in your analysis of the use of hot water tanks for heating.

Yours truly,

Joseph Chorostkowski

JC/ec

J & R MECHANICAL LTD.

P.O. BOX 1541 - YELLOWKNIFE, N.W.T. X1A 2P2
873-2392 920-2495

March 14, 1990

Howell-Mayhew Engineering, Inc.
15006 - 103 Avenue
Edmonton, Alberta
T5P 0N8

Attention: Rick Thrall

Dear Rick:

RE: HEATING COMPARISONS

In reviewing the costs which occured, I have come up with the following results:

10 Units Hall Beach Material

Ventilation	3%
Plumbing	51%
Heating	46%

5 Units Repulse Bay Material

Ventilation	10%
Plumbing	35%
Heating	55%

Hoping this information will help you in evaluating the difference between using the hot water tanks and boilers for heating purposes.

Regards,

Joseph Chorostkowski

JC/bj

APPENDIX "B"

FUEL CALCULATIONS

Fuel Consumptions and Costs

The following fuel consumptions are averages for combined space and domestic hot water heating based on a 100 square foot house modeled by HOT-2000.

Boiler system fuel consumption in Yellowknife is 1600 liters.
DHW system fuel consumption in Yellowknife is 2280 liters.

Boiler system fuel consumption in Repulse Bay is 2470 liters.
DHW system fuel consumption in Repulse Bay is 3520 liters.

Fuel costs for a boiler in Yellowknife.

$$\frac{1600 \text{ liters}}{\text{year}} \times \frac{\$.270}{\text{liter}} = \$432 \text{ / year}$$

Fuel costs for a DHW tank in Yellowknife.

$$\frac{2280 \text{ liters}}{\text{year}} \times \frac{\$.270}{\text{liter}} = \$616 \text{ / year}$$

Fuel costs for a Boiler in Repulse Bay.

$$\frac{2470 \text{ liters}}{\text{year}} \times \frac{\$.450}{\text{liter}} = \$1,112 \text{ / year}$$

Fuel costs for a DHW tank in Repulse Bay.

$$\frac{3520 \text{ liters}}{\text{year}} \times \frac{\$.450}{\text{liter}} = \$1,584 \text{ / year}$$

APPENDIX "C"

HOT-2000 HEAT LOSS SIMULATION PRINTOUTS

```
*****************************************
*                                       *
*                                       *
*              Hot-2000                 *
*        Fortran Version 5.05f          *
*  Energy, Mines and Resources CANADA   *
*              Nov 30, 1988             *
*                                       *
*                                       *
*****************************************
```

CLIENT NAME: Northwest Territories Housing
ADDRESS : Repulse Bay, NWT.

Weather Data is for RESOLUTE, NORTHWEST TERRITORY

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area	=	250.7 m2
Average Natural Infiltration Rate	=	.30 ACH
Average Ventilation Rate (Unbalanced)	=	.00 ACH (0 L/s)

*** SPACE HEATING SYSTEM ***

Primary Space Heating Fuel	:	Oil
Space Heating Equipment	:	Conventional furnace/boiler
Space Heating Equipment Manufacturer	:	WEIL-McLEAN BOILER
Space Heating Equipment Model	:	P-386W
Space Heating System Output Capacity	=	33.4 kW
SGUE Seasonal Efficiency	=	77 %

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -44.0 C	=	5140. Watts
Gross Space Heating Load	=	92653. MJ
Sensible Daily Heat Gain From Occupants	=	4.00 kWh/day
Usable Internal Gains	=	17515. MJ
Usable Internal Gains Fraction	=	18.9 %
Usable Solar Gains	=	8486. MJ
Usable Solar Gains Fraction	=	9.2 %
Auxiliary Energy Required	=	66653. MJ
Ventilation Equipment Electrical Contribution	=	0. MJ
Furnace/Boiler Annual Energy Consumption	=	86562. MJ

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Oil
Water Heating Equipment : Conventional oil-fired tank

Water Heating Equipment Manufacturer : COMPANION TANK FOR BOILER
Water Heating Equipment Model : HEAT MAKER
Water Heating Equipment Tank Capacity = 136.4 Litres
Seasonal Efficiency = 77 %

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption = 90.9 Litres /day
Estimated Domestic Water Heating Load = 6600. MJ

PRIMARY Domestic Water Heating Energy Consumption = 8572. MJ

*** LIGHTING AND APPLIANCES SUMMARY ***

Daily Electrical Load = 9.0 kWh/day
Estimated Annual Energy Consumption = 3285. kWh

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	=	86562. MJ =	24045.1 kWh
Ventilator Electrical Consumption: Heating Hours	=	0. MJ =	.0 kWh
Estimated Annual DHW Heating Energy Consumption	=	8572. MJ =	2381.0 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	=	95134. MJ =	26426.1 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	=	91368. MJ =	25380.1 kWh
Estimated Annual Base Electrical Energy Consumption	=	11826. MJ =	3285.0 kWh
Ventilator Electrical Consumption: Non Heating Hours	=	0. MJ =	.0 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

FUEL	SPACE HEATING	+ DHW HEATING	+ APPLIANCES	= TOTAL
Oil (Litres)	2247.0	222.5	.0	2469.5 Litres
Electricity (kWh)	.0	.0	3285.0	3285.0 kWh

```
*****************************************
*                                       *
*              Hot-2000                 *
*         Fortran Version 5.05f         *
*   Energy, Mines and Resources CANADA  *
*              Nov 30, 1988             *
*                                       *
*****************************************
```

CLIENT NAME: Northwest Territories Housing
ADDRESS : Repulse Bay, NWT.

Weather Data is for RESOLUTE, NORTHWEST TERRITORY

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area	=	250.7 m2
Average Natural Infiltration Rate	=	30 ACH
Average Ventilation Rate (Unbalanced)	=	.00 ACH (0 L/s)

*** SPACE HEATING SYSTEM ***

Primary Space Heating Fuel : Oil
Space Heating Equipment : Conventional furnace/boiler

Space Heating Equipment Manufacturer	:	GSW HOT WATER TANK
Space Heating Equipment Model	:	JOHN WOODS 307
Space Heating System Output Capacity	=	10.0 kW
SGUE Seasonal Efficiency	=	54 %

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -44.0 C	=	5140. Watts
Gross Space Heating Load	=	92653. MJ
Sensible Daily Heat Gain From Occupants	=	4.00 kWh/day
Usable Internal Gains	=	17515. MJ
Usable Internal Gains Fraction	=	18.9 %
Usable Solar Gains	=	8486. MJ
Usable Solar Gains Fraction	=	9.2 %
Auxiliary Energy Required	=	66653. MJ
Ventilation Equipment Electrical Contribution	=	0. MJ
Furnace/Boiler Annual Energy Consumption	=	-123431. MJ

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Oil
Water Heating Equipment : Conventional oil-fired tank

Water Heating Equipment Manufacturer : GSW INDUSTRIES, SPACE HEATER
Water Heating Equipment Model : JW 307 ALSO SPACE HEATER
Water Heating Equipment Tank Capacity = 136.4 Litres
Seasonal Efficiency = 54 %

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption = 90.9 Litres /day
Estimated Domestic Water Heating Load = 6600. MJ

PRIMARY Domestic Water Heating Energy Consumption = 12223. MJ

*** LIGHTING AND APPLIANCES SUMMARY ***

Daily Electrical Load = 9.0 kWh/day
Estimated Annual Energy Consumption = 3285. kWh

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	= 123431. MJ	= 34286.5 kWh
Ventilator Electrical Consumption: Heating Hours	= 0. MJ	= .0 kWh
Estimated Annual DHW Heating Energy Consumption	= 12223. MJ	= 3395.2 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	= 135654. MJ	= 37681.6 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	= 91368. MJ	= 25380.1 kWh
Estimated Annual Base Electrical Energy Consumption	= 11826. MJ	= 3285.0 kWh
Ventilator Electrical Consumption: Non Heating Hours	= 0. MJ	= .0 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

FUEL	SPACE HEATING	+ DHW HEATING	+ APPLIANCES	= TOTAL
Oil (Litres)	3204.0	317.3	.0	3521.3 Litres
Electricity (kWh)	.0	.0	3285.0	3285.0 kWh

```
*****************************************
*                                       *
*                Hot-2000               *
*          Fortran Version 5.05f        *
*    Energy, Mines and Resources CANADA *
*               Nov 30, 1988            *
*                                       *
*****************************************
```

CLIENT NAME: Northwest Territories Housing
ADDRESS : Yellowknife, NWT.

Weather Data is for YELLOWKNIFE, NORTHWEST TERRITORY

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area	=	250.7 m2
Average Natural Infiltration Rate	=	.30 ACH
Average Ventilation Rate (Unbalanced)	=	.00 ACH (0 L/s)

*** SPACE HEATING SYSTEM ***

Primary Space Heating Fuel	:	Oil
Space Heating Equipment	:	Conventional furnace/boiler
Space Heating Equipment Manufacturer	:	WEIL-McLEAN BOILER
Space Heating Equipment Model	:	P-386W
Space Heating System Output Capacity	=	33.4 kW
SGUE Seasonal Efficiency	=	77 %

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -43.0 C	=	5061. Watts
Gross Space Heating Load	=	64560. MJ
Sensible Daily Heat Gain From Occupants	=	4.00 kWh/day
Usable Internal Gains	=	16334. MJ
Usable Internal Gains Fraction	=	25.3 %
Usable Solar Gains	=	7444. MJ
Usable Solar Gains Fraction	=	11.5 %
Auxiliary Energy Required	=	40782. MJ
Ventilation Equipment Electrical Contribution	=	0. MJ
Furnace/Boiler Annual Energy Consumption	=	52964. MJ

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Oil
Water Heating Equipment : Conventional oil-fired tank

Water Heating Equipment Manufacturer : COMPANION TANK FOR BOILER
Water Heating Equipment Model : HEAT MAKER
Water Heating Equipment Tank Capacity = 136.4 Litres
Seasonal Efficiency = 77 %

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption = 90.9 Litres /day
Estimated Domestic Water Heating Load = 6600. MJ

PRIMARY Domestic Water Heating Energy Consumption = 8572. MJ

*** LIGHTING AND APPLIANCES SUMMARY ***

Daily Electrical Load = 9.0 kWh/day
Estimated Annual Energy Consumption = 3285. kWh

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	= 52964. MJ	= 14712.1 kWh
Ventilator Electrical Consumption: Heating Hours	= 0. MJ	= .0 kWh
Estimated Annual DHW Heating Energy Consumption	= 8572. MJ	= 2381.0 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	= 61535. MJ	= 17093.2 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	= 74086. MJ	= 20579.5 kWh
Estimated Annual Base Electrical Energy Consumption	= 11826. MJ	= 3285.0 kWh
Ventilator Electrical Consumption: Non Heating Hours	= 0. MJ	= .0 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

FUEL	SPACE HEATING	+ DHW HEATING	+ APPLIANCES	= TOTAL
Oil (Litres)	1374.8	222.5	.0	1597.3 Litres
Electricity (kWh)	.0	.0	3285.0	3285.0 kWh

```
*****************************************
*                                       *
*                 Hot-2000              *
*          Fortran Version 5.05f        *
*    Energy, Mines and Resources CANADA *
*               Nov 30, 1988            *
*                                       *
*****************************************
```

CLIENT NAME: Northwest Territories Housing
ADDRESS : Yellowknife, NWT.

Weather Data is for YELLOWKNIFE, NORTHWEST TERRITORY

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area	=	250.7 m2
Average Natural Infiltration Rate	=	.30 ACH
Average Ventilation Rate (Unbalanced)	=	.00 ACH (0 L/s)

*** SPACE HEATING SYSTEM ***

Primary Space Heating Fuel : Oil
Space Heating Equipment : Conventional furnace/boiler

Space Heating Equipment Manufacturer	:	GSW HOT WATER TANK
Space Heating Equipment Model	:	JOHN WOODS 307
Space Heating System Output Capacity	=	10.0 kW
AFUE Seasonal Efficiency	=	54 %

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -43.0 C	=	5061. Watts
Gross Space Heating Load	=	64560. MJ
Sensible Daily Heat Gain From Occupants	=	4.00 kWh/day
Usable Internal Gains	=	16334. MJ
Usable Internal Gains Fraction	=	25.3 %
Usable Solar Gains	=	7444. MJ
Usable Solar Gains Fraction	=	11.5 %
Auxiliary Energy Required	=	40782. MJ
Ventilation Equipment Electrical Contribution	=	0. MJ
Furnace/Boiler Annual Energy Consumption	=	75522. MJ

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Oil
Water Heating Equipment : Conventional oil-fired tank

Water Heating Equipment Manufacturer : GSW INDUSTRIES, SPACE HEATER
Water Heating Equipment Model : JW 307 ALSO SPACE HEATER
Water Heating Equipment Tank Capacity = 136.4 Litres
Seasonal Efficiency = 54 %

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption = 90.9 Litres /day
Estimated Domestic Water Heating Load = 6600. MJ

PRIMARY Domestic Water Heating Energy Consumption = 12223. MJ

*** LIGHTING AND APPLIANCES SUMMARY ***

Daily Electrical Load = 9.0 kWh/day
Estimated Annual Energy Consumption = 3285. kWh

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	=	75522. MJ =	20978.4 kWh
Ventilator Electrical Consumption: Heating Hours	=	0. MJ =	.0 kWh
Estimated Annual DHW Heating Energy Consumption	=	12223. MJ =	3395.2 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	=	87745. MJ =	24373.6 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	=	74086. MJ =	20579.5 kWh
Estimated Annual Base Electrical Energy Consumption	=	11826. MJ =	3285.0 kWh
Ventilator Electrical Consumption: Non Heating Hours	=	0. MJ =	.0 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

FUEL		SPACE HEATING + DHW HEATING +	APPLIANCES =	TOTAL
Oil	(Litres)	1960.4 + 317.3	.0	2277.7 Litres
Electricity	(kWh)	.0 + .0	3285.0	3285.0 kWh

APPENDIX "D"

NWTHC MAINTENANCE COSTS

March 14, 1989

CLARENCE EMBERLY,
MANAGER, MAINTENANCE UNIT,
PROPERTY MANAGEMENT & PROGRAM OPERATIONS,
COMMUNITY & PROGRAM SERVICES.

Re: Maintenance Cost Comparison Between Forced Air Furnaces and Hydronics Systems in the Hay River District

Following is the information you requested concerning the maintenance costs of forced air furnaces and boilers.

In compiling this report I extracted data from the HMRS on 410 units covering the period of time from April 1, 1988 to January 31, 1989.

Overall costs were as follows:

UNITS	LABOUR	MATERIAL	CONTRACT	TOTAL	COST PER UNIT
410	$80433	$30702	$3548	$114683	$279.71

Currently we have 42 boilers heating by hydronics 150 Units in the Hay River District. Breakdown of costs are as follows:

UNITS	LABOUR	MATERIAL	CONTRACT	TOTAL	COST PER UNIT
150	$28033	$4718	$3548	$37300	$248.00

Note Included in the labour total is the cost of daily boiler checks

Currently we are heating 200 Units by Forced Air Furnaces in the Hay River District. Breakdown of costs are as follows:

UNITS	LABOUR	MATERIAL	CONTRACT	TOTAL	COST PER UNIT
200	$51400	$25983	NIL	$77383	$387.62

NOFHIWest Territories Housing Corporation

The information you requested concerning maintenance on Hot Water Heaters cannot be isolated as precisely as Heating Repairs because the HWTS groups water heater along with other major appliances under Activity code 708. For your information here is the breakdown of Activity Code 708:

UNITS	LABOUR	MATERIAL	CONTRACT	TOTAL	COST PER UNIT
410	$13822	$22807	$562	$37271	$90.00

I trust this is the information you require.

Bill Fandrick,
Maintenance Manager,
Hay River District Office

cc Tom Beaulieu
Carl Simms
Gordon Norberg
John Lanskail
Ernie Romans

APPENDIX "E"

EXAMPLE CALCULATIONS

EXAMPLE CALCULATIONS

Tank Replacement Calculation

$$\text{Tank Replacements} = \frac{\text{Length of Analysis}}{\text{Life of DHW}} \times \frac{\text{1 Tank}}{\text{Length of Analysis}}$$

$$\frac{\text{20 Years for the Analysis}}{\text{10 years}} \times \frac{\text{1 Tank}}{\text{20 years}} = 0.10 \text{ Tank/Year}$$

Tank Replacement Cost Calculations

Cost per year in Yellowknife ($650 + $200) X .100 = $85

Cost per year in the Eastern Arctic ($975 + $300) X .100 = $127

Present Value Calculations

Present value of Maintenance for a boiler in Yellowknife is,

$$\$290 \times \left[\frac{(1.05)^1 + (1.05)^2 + \ldots\ldots + (1.05)^{20}}{(1.07)^1 + (1.07)^2 + \ldots\ldots + (1.07)^{20}}\right] = \$4,786$$

Present value of fuel used by a boiler in Yellowknife is,

$$\$432 \times \left[\frac{(1.04)^1 + (1.04)^2 + \ldots\ldots + (1.04)^{20}}{(1.07)^1 + (1.07)^2 + \ldots\ldots + (1.07)^{20}}\right] = \$6,496$$

Present worth of replacement of a DHW tank in Yellowknife is:

$$\$85 \times \left[\frac{(1.05)^1 + (1.05)^2 + \ldots\ldots + (1.05)^{20}}{(1.07)^1 + (1.07)^2 + \ldots\ldots + (1.07)^{20}}\right] = \$1,403$$

Present worth of replacement of a DHW tank in the Arctic is,

$$\$127 \times \left[\frac{(1.05)^1 + (1.05)^2 + \ldots\ldots + (1.05)^{20}}{(1.07)^1 + (1.07)^2 + \ldots\ldots + (1.07)^{20}}\right] = \$2,096$$

Uniform Capital Recovery Calculation

$$0.07 \times \left[\frac{(1 + 0.05)^{20}}{(1 + 0.07)^{20} - 1}\right] = .09439$$

APPENDIX "F"

RECOMMENDED LITERATURE

RECOMMENDED REFERENCE PAPERS
RELATED TO POTABLE WATER SOURCE SPACE HEATING

1. Equipment Sizing Procedures for Combination Space-Heating/Water-Heating Systems; J.A. Pietsch, S.G. Talbert; ASHRAE paper #3280.

2. Synergism of a Combination Space-Heating/Water-Heating Appliance; J.A. Pietsch; ASHRAE paper PO-86-09 No.1.

3. Combination Water-Heating/Space-Heating Appliance Performance; B.R. Subherwal; ASHRAE paper PO-86-09 No.3.

4. Integrating Space and Water Heating - The Easy Way; E.A Nordstrom and J.J. Fuller; ASHRAE paper NT-87-11-5.

5. Combination Warm Air Space Heating/Potable Water Systems; P.F. Swenson and D.R. Gilbert; NT-87-20-2.

6. Evaluation of Field Combination Residential Appliances; BR Laboratories, Inc., Huntington Beach, CA., Aug. 87.

7. Water Analysis Report on Combined Space/Water Heating Systems; Columbia Gas System Service Corporation Research Department; Dr. C. Thomas Bell, Oct. 87.

8. Field Investigation of Domestic Hot Water Tanks as Space Heating Appliances; Howell Hayhew Engineering Inc.; W.J. Hayhew and R.H. Thrall, Edmonton, Alberta. Apr. 89

RECOMMENDED NEWS ARTICLES RELATED
TO POTABLE WATER SOURCE SPACE HEATING

1. Air Conditioning, Heating & Refrigeration News; May 20, 1985; page 8.

2. Air Conditioning, Heating & Refrigeration News; June 3, 1985; page 1.

3. Air Conditioning, Heating & Refrigeration News; July 1, 1985; page 1.

4. American Gas Association Fact Sheet; October 1987.

5. Energy Design Update; January 1988; page 6.

6. Energy Design Update; June 1989; page 3.

7. Apollo Hydroheat System - Product Literature.

APPENDIX "G"

HEAT TRANSFER

HEAT TRANSFER THROUGH A METAL JACKET WALL